4.0 RCM IMPLEMENTATION

4.1 Initial Analysis. Results of the initial RCM analysis should be implemented and sustained according to the RCM plan and the following additional procedures and processes within this chapter.

4.2 Task packaging. The task requirements that result from the RCM analysis may have varying intervals. It would be extremely cumbersome and difficult to manage a maintenance program based entirely on engineering interval(s) resulting from the RCM analysis. Therefore, the tasks must be packaged together in groups so that a number of tasks can be accomplished each time the aircraft is down for PM.

Packaging of tasks is accomplished by considering level of maintenance, engineering interval, and task requirements (i.e., support equipment (SE), work areas). Fleet maintenance personnel inputs are extremely important and should be solicited prior to initiating the packaging process. Only PM task requirements determined through RCM and/or dictated by other sources are packaged. AE tasks that collect information while the equipment is in service are done at the packaged interval of the preventive task they were developed for.

4.2.1 The Packaging Process. First convert all task intervals to a common measurement base (usually calendar time). All tasks are then displayed on a time line to see if there are natural groupings. The goal is to adjust task intervals up or down so that groups of tasks are formed. These groupings should not reflect any predetermined intervals. Non-safety intervals can be adjusted either up or down. Safety intervals on the other hand can only be adjusted down.

Since safety intervals are limited in their ability to be adjusted, use these tasks to determine the groupings, then adjust non-safety tasks to the resulting groups. Some tasks will not be able to be adjusted to fit into any of the groups. These tasks will be included at the engineering interval, in a special maintenance package.

After completion of the packaging process, the "packaged" intervals are recorded along with the engineering intervals. By recording both "engineering" and "packaged" intervals, essential data for future revisions and updates to the PM requirements is recorded. The record of packaged intervals allows comparison with engineering intervals to determine the thought processes used to arrive at the scheduled maintenance intervals.

4.2.2 Packaging Considerations. The following list should be considered when packaging PM requirements:

a. Grouping all the requirements in a specific work area has its advantages, especially if access is time consuming. However, overloading a work area with too many maintenance personnel is poor procedure. Attempt to evenly distribute the personnel in the different work areas.

b. Tasks which use the same SE should also be grouped together.

c. The packaging of PM tasks affects such things as the man-hours consumed to schedule and perform maintenance, aircraft availability, and, in some cases, the structure of the maintenance organization. Therefore, it is of utmost importance that the PM program be as simple and straightforward as possible, and that fleet operator and maintenance personnel inputs are considered. This will also increase the probability of faithful implementation by maintenance personnel.

4.3 Sustaining RCM

4.3.1 RCM Review/Update

4.3.1.1Proactive Analysis. Proactive analysis data is primarily acquired through the Maintenance, Material, Management (3-M) system. The NALDA and ECA systems are used to provide the required data. LMDSS will also be utilized upon complete implementation. Other data sources can be used to gain additional data (locally developed data collection programs, contractor developed data collection programs, etc.).

a. Top Degrader Analysis. Top degraders are “flag s” of potential bad actors to be further analyzed in detail to determine the actual causes of failure. NALDA/ECA data retrieval is initially performed to the sub-system (WUC 4) level. Degrader measurement factors which can be ranked include: MMH/FH, NMC rates, MA/FH, and failures per flight hour (VF/FH). Top degraders are analyzed to determine the causes of failure for the highest ranked items. The RCM analysis for these items should be reviewed, and updated if necessary. Other corrective action should also be considered, if necessary, to alleviate the failures.

b. Trend Analysis. Trend analysis is normally performed as follows: Means and standard deviations are calculated for each parameter for a pre-determined baseline period. Upper and lower control limits of two standard deviations from the mean are calculated. Parameters (such as VF/FH, MMH/FH, etc.) are then monitored for items which exceed the control limits. The RCM analysis for these items should be reviewed, and updated if necessary, after trend analysis and problem characterization. Other corrective action should also be considered, if necessary, to alleviate the failures. Additional statistical processes may also have to be utilized. Appendix B is a trend analysis example.

c. PM Requirements Document Reviews. A review of documents which contain PM requirements should be accomplished periodically. Fleet input on ineffective maintenance tasks or new problem areas should be solicited.

The following type of documents should be reviewed:

(1) Maintenance Requirement Cards (MRCs)
(2) Depot Level Maintenance Specification(s)
(3) Any other Maintenance information Manuals (MIMs) which may contain PM procedures that accompany corrective maintenance tasks.

The subject documents should be reviewed for the following:

(1) Processes or materials which have become obsolete or outdated. This would include taking advantage of new technologies, such as incorporating a new Non -Destructive Inspection (NDI) technique which may detect smaller flaws allowing a longer inspection interval, or replacing older materials such as paints or sealants with less environmentally hazardous or less expensive ones. These reviews should be coordinated and supported with local Materials Laboratory personnel.
(2) The number of RCM history log entries documented against the document. This will provide an indication of the number of tasks that have been identified through RCM as requiring addition, deletion, or modification. The RCM history log is discussed in detail in paragraph 4.3.2.
(3) All documents should be reviewed by each RCM analyst for items under his/her cognizance. Any changes resulting from the document reviews should be documented in the RCM history log. The results of any RCM updates resulting from the document reviews should also be documented in the RCM history log.

d. Task Packaging Reviews. Task packaging reviews should be conducted at two year intervals, as a minimum, following establishment of a task package baseline. Task packaging reviews should evaluate phase intervals, special inspection calendar and event intervals. The cumulative effect of any packaging changes on the maintenance program and maintenance activities should be evaluated prior to implementation of those changes.

e. Fleet Leader Programs. The specific requirements for this program should be developed after the initial RCM analyses are completed. Fleet leader inspections for the aircraft should consist of "opportunity" inspections by ISST/IPT personnel. For example, ISST/IPT engineer(s) would participate on a not to interfere basis with the first phase inspection of the first one or two aircraft to reach multiples of 1000 flight hours (or other multiple). Prior to the inspection, inspection areas and documentation methods would be identified. In the event that a depot maintenance program is established, these inspections would be supplemented by regular visits to the depot line by ISST/IPT personnel.

Proactive analysis results should be periodically reviewed by each cognizant RCM analyst for his/her assigned systems. Reports should be prepared to summarize the results of the periodic condition monitoring analyses and provided to the APML, APMS&E, PMA, and other ISST/IPT members (as required). The results of any RCM reviews or updates resulting from condition monitoring should be documented in the RCM history log whether or not a change to PM requirements is necessary.

4.3.1.2 Reactive Analysis.

a. Failure Related Reviews. The process for responding to reported problems will vary depending on the type of failure, means of reporting, and whether a vendor or organic activity must perform the failure analysis. However, certain basic steps apply to all processes. The interface of these processes with the RCM/AE program are described in the following paragraphs and shown in FIGURE 4-1.

The following paragraphs are intended to be a general description and should not be considered comprehensive. There may be additional actions required, such as stress analysis, testing, etc. Coordination with other activities such as NAVAIR, fleet maintenance personnel, or contractors, etc. may also be required. Some actions may be directed by higher authority. All of these steps are not necessarily a direct part of the RCM/AE process or performed by RCM personnel; however, RCM personnel should be aware of all actions taken during the process and will be involved in recommendations for corrective action through interface with other personnel and activities. Although this process shows a specific logical order, in some cases the steps may be performed concurrently or in a different order.

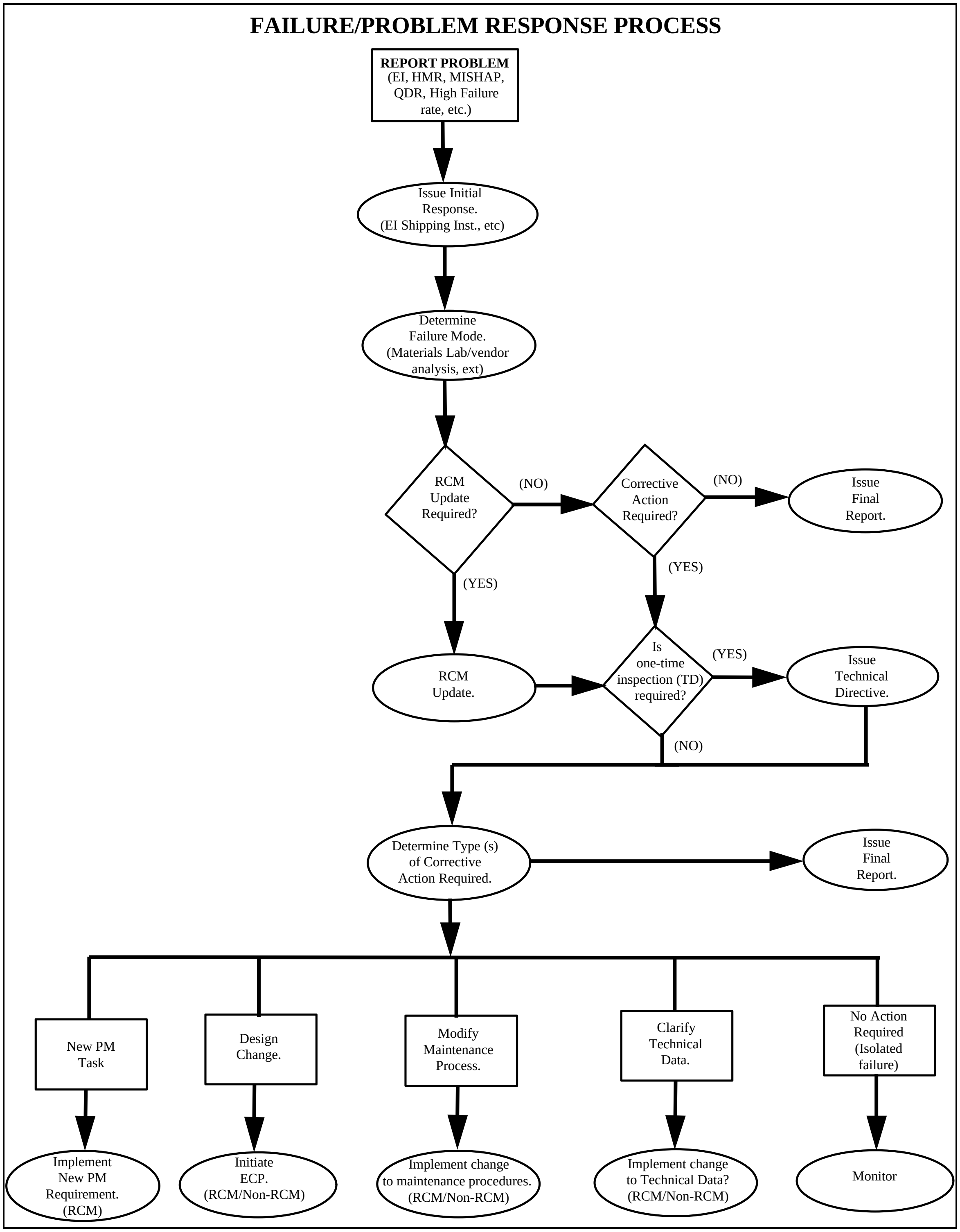

FIGURE 4-1. Failure/Problem Response Process

(1) Step 1: Problem reported. The process is started upon receipt of a report of the problem. The problem could be reported formally through an EI request, HMR, QDR, TPDR, mishap report, etc. or informally such as through a phone call from squadron maintenance personnel. Depending upon the type of report, an initial response, such as a preliminary EI report with shipping instructions for the EI exhibit, may be required. The RCM lead engineer should be provided an information copy of the problem report or a conversation record copy if the report was verbal. Primary responsibility for the investigation and resolution of the problem may be assigned to a RCM, systems, structures, or avionics engineer as appropriate. If the assigned engineer is not a RCM analyst, then a RCM analyst should work with the assigned engineer to address RCM and PM issues.

(2) Step 2: Failure mode determination. This step is the primary research and analysis part of the process. This step will include failure analysis by a vendor or materials lab, background data collection from squadron or maintenance personnel, etc. It will also include actions such as fatigue, stress, fracture mechanics, and statistical analyses to determine PM task intervals, or probability of future occurrences of this failure mode. Although a specific failure mode should be determined prior to any corrective action being imposed, certain responses will often be required prior to this step being complete. For instance, an inspection bulletin may be required immediately if a specific failure mode is suspected for safety of flight concerns. The assigned engineer should be responsible for ISST/IPT involvement in this step, although other individuals or organizations may also be involved, such as the materials lab, NAVAIR, contractors, vendors, etc. If the cognizant RCM analyst is not the assigned engineer, he/she should be provided with data as the investigation progresses.

(3) Step 3: RCM Review. At this step the beginning of the decisions on corrective action begin. If the assigned engineer is not the cognizant RCM analyst, the RCM analyst should provide recommendations on corrective action to the assigned engineer, with regard to changes in the PM program. Any decisions on scheduled maintenance requirements must be based on the results of a RCM analysis.

(a) If this is a completely new failure mode a RCM analysis will be performed.

(b) If there is a current RCM analysis, it should be reviewed to ensure that the failure does not change any of the data in the analysis. If so, a RCM update should be performed.

(c) If the RCM is current, a determination should be made as to whether the effects of the failure require corrective action. If not, a final report stating this fact may be issued, if required. If the effects do require corrective action, step 4. is performed.

(4) Step 4: One -time Inspection. If not accomplished previously, the need to issue an inspection bulletin (technical directive) is determined. If the possibility of additional failures exist prior to the implementation of other corrective actions, and failure effects are unacceptable, a bulletin must be issued. NAVAIR

00-25-300 provides direction for preparing and issuing technical directives. If the inspection bulletin will not permanently mitigate the effects of the subject failure mode, continue with step 5.

(5) Step 5: Corrective Action. The corrective actions necessary for final resolution of the problem are determined. This may be a single action or a combination of solutions. Corrective actions should be agreed upon by the assigned engineer, cognizant RCM analyst, and others as applicable, or may be directed by higher authority.

(a) A PM requirement may be added or modified that would preclude the failure or detect an impending failure before it occurs. Any change to PM requirements should be determined through RCM analysis. Changes to PM requirements directed by higher authority which disagree with RCM recommendations will be documented as such in the RCM history log.

(b) Design changes may be implemented to preclude additional failures. Design changes are implemented through the Rapid Action Minor Engineering Change (RAMEC)/ECP process. Recommendations to incorporate RAMECs/ECPs may or may not be a result of the RCM analysis.

(c) A change to maintenance procedures or processes may be used to preclude additional failures. Some examples are: changing a type of sealant used in an assembly process, changing torque requirements for fasteners, or adding quality assurance steps to a maintenance requirement. These types of actions are usually not directly based on RCM results, but may be used to make a current requirement more effective.

(d) Clarification of an ambiguous current requirement may be necessary, when failures are the result of improper interpretation of that requirement, or failure of the requirement to perform as intended. Clarifications can be accomplished by changes to the appropriate documentation (MRC, MIM, etc.) or through Maintenance Engineering Reports (MER). If the change affects a PM requirement, it should be documented in the RCM history log, even if the RCM is not affected.

The results of the RCM review and/or update, as well as any recommendations for corrective action should be documented in the RCM history log.

b. Updates for Design C hanges. RCM analysis should be reviewed or updated to assess supportability during any modification processes. When a formal change; Air Frames Change (AFC), Accessory Change (AYC), ECP, etc. is received for review or generated by the ISST/IPT, the RCM update, if applicable, should also be available for review. The cognizant RCM analyst should ensure that action is being taken to update the RCM analysis, if required, and that the RCM analysis is acceptable.

4.3.2 RCM History Log. In addition to the IRCMS database which stores only current requirements and the analysis decisions that led to them, a method of providing an audit trail for changes to RCM/PM requirements over time is also required. This audit trail not only identifies factors which led to changes in the PM program, but also identifies when reviews were performed that did not lead to any changes.

The RCM history log provides a means to review the decisions that led to a RCM update. It also helps identify the level of effort expended for RCM related efforts in the RCM/AE program, and provides a method of evaluating the effectiveness of the RCM/AE program.

The RCM history log can be an automated database or document. A RCM history log entry should be completed any time one of the reactive or proactive tasks described above causes a review of the RCM analysis, whether or not a RCM update is performed. Various parts of the log are completed at the time the process is initiated, at completion of the RCM review/update, and when updated requirements are incorporated. An example of information which should be contained in the RCM history log includes, but is not limited to, the following:

a. Previous/current PM task, document, card, task no., etc.

b. Previous RCM Analysis? (Y/N)

c. Man-hours required to perform RCM analysis

d. RCM analysis recommendations

e. Packaged interval (if applicable)

f. New/modified PM task, document, card, task no., etc.

g. Cost or savings of new requirement

4.3.3 Age Exploration (AE). AE is the process used to sustain and optimize a PM program. The RCM analysis furnishes conservative PM requirements when insufficient information exists to create preventive requirements based on real data. AE provides a systematic procedure for collecting the information necessary to reduce or eliminate this gap in knowledge. AE procedures supply information to determine the applicability of some PM tasks and to evaluate the effectiveness of others. For new equipment, AE provides information necessary to adjust the initial inspection interval or assess the applicability and effectiveness of a task. For mature equipment, AE provides information to evaluate existing tasks, thereby optimizing the PM program.

Specific AE tasks will be developed through the RCM analysis process to update default answers used in the analysis process. Specific AE inspections must be evaluated to determine whether each inspection is necessary and cost -effective.

4.3.3.1 Selection Of Candidates. The identification of those ite ms which may require AE is a direct output of a RCM analysis. When applying RCM, a "default strategy" is used if insufficient information exists to make a definitive answer to the logic tree questions. This strategy ensures a conservative, safe answer which can be evaluated through AE. New items added as a result of modifications, ECPs, or changes in operating environment or utilization may warrant AE to determine the effect on the PM program, but these changes must first be analyzed through RCM to determine if AE is required. While AE candidates may result from output of the RCM analysis they can also result from other sources such as PMA or NAVAIR mandates. Available AE resources and fleet impact should always be considered when selecting AE candidates.

4.3.3.2 Design Of AE Tasks. An AE requirement is developed for each AE candidate, and like RCM requirements, is directed at a single failure mode. To fully define the requirement, the following need to be known:

a. Sample size. AE is a sampling pro gram to collect data from a sample just large enough to produce the required confidence in the results, not from the entire inventory.

b. Study period. AE tasks are implemented for only as long as it takes to get sufficient data to resolve the requirement which drove them in the first place.

c. Initial interval. Some failure modes do not develop for some time. The initial interval is the age at which the AE task will be initiated. There must be data to show that the failure mode is not expected to appear before the initial interval.

d. Repeating interval. The repeating interval is the interval at which the AE task will be repeated once it has been initiated.

e. Precision required for measurements. Any measurements that will be made according to the AE task should only require the degree of precision necessary to determine the unknown data. Requiring greater precision than necessary can be more expensive, difficult, and provide more opportunity for mistakes.

f. Task description. A ge neral statement of what action is required needs to be described. Usually the task description will include inspection for the failure mode and recording of it's condition.

g. Analysis Type. Two main analysis types for AE are Degradation or Actuarial analysis. Selection of which type of analysis to use is dependent on the failure mode. These analyses are discussed in detail in paragraphs 5.2 and 5.3.4 respectfully.

4.3.3.3 Prioritizing AE Tasks. In many cases, there is insufficient funding available to implement all AE requirements on all candidates. Thus, we must prioritize the AE efforts to concentrate on those tasks which will benefit the organization the most, in terms of safety and economics. AE inspections can be classified according to the following criteria:

a. Priority 1. AE inspections for SSIs which have crack failure modes, AE inspections developed to validate maintenance requirements which are safety related, or have high cost savings benefits.

b. Priority 2. AE inspections whic h require no additional resources and are developed to validate maintenance requirements which do use significant maintenance resources (time, equipment, spares) or affect operational availability of the aircraft.

c. Priority 3. AE inspections which require additional resources and are developed to validate maintenance requirements which use significant maintenance resources (time, equipment, spares) or affect operational availability of the aircraft.

d. Priority 4. AE inspections which do not m eet any of the above criteria.

Priority 1 and 2 AE inspections should be implemented unless there is justification for not doing so. Priority 3 inspections should be evaluated to determine whether the benefits of implementing the task would exceed the costs. Priority 4 AE inspections should not be implemented unless AE decision logic diagram. some justification is provided. Figure 4-2 provides the AE decision logic diagram.

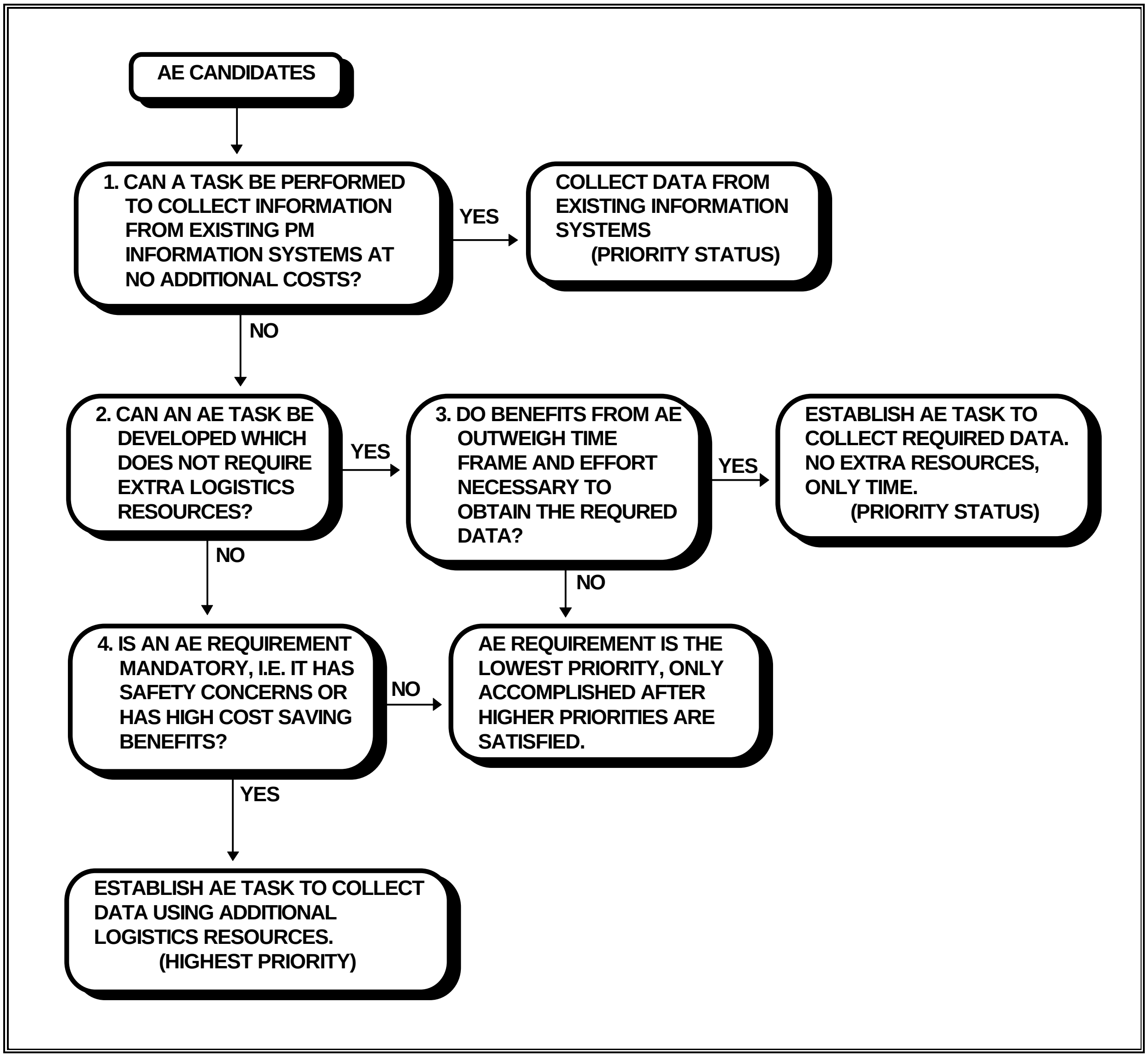

FIGURE 4-2. Age Exploration Decision Diagram

4.3.3.4AE Inspection Implementation. The following are some acceptable methods of implementing AE inspections:

a. Data collection by the cognizant RCM analyst from available sources such as 3-M, or local depot/overhaul databases.

b. Depot level sampling tasks, carried out in conjunction with depot level maintenance. This method is usually the most effective for SSI AE inspections.

c. Age Exploration Bulletins (AEB). Specific direction for AEBs is given in NAVAIR 00 -25-300. This method is us ed for direct data collection from O-level or contractor maintenance locations, if required. Data should be provided via AE Data Sheet, or other means, to the ISST/IPT. Appendix C provides sample AE data sheets.

d. Equipment History Records (EHR). EHRs are useful for tracking serialized components. Direction on the use of EHRs is provided in OPNAVINST 4790.2F and NAVAIRINST 4790.3B.

e. Fleet leader inspections. Fleet leader inspections sample those items which have accumulated the most operational time and exposure. This method is usually is most effective for SSI tasks.

Sample sizes are normally determined through statistical analysis to determine the minimum required number of samples and inspections to adequately gather the required data. As the RCM is completed, and specific requirements are determined, additional guidance on sample sizes may be required.

For any RCM analysis performed or updated, the cognizant RCM analyst should be responsible for development of an applicable AE inspection (if required) in accordance with applicable instructions, and determining if that task should be implemented. If so, the cognizant RCM analyst should implement the inspection, incorporate the results into the RCM analysis upon completion of the inspection, and delete the requirement for the inspection when complete. Upon completion of the AE inspection when complete, a summary of the results will be documented in the RCM history log whether or not a change to PM requirements is made.

The status of all AE candidates (those items subject to specific AE inspections, and results of data) should be provided on a periodic basis to the APML and PMA in an AE Status Report.

4.3.3.5Applying Results of AE Analysis. The last requirement of the AE process is applying the results of the analyses to the PM program. AE can not change the PM requirement without going through RCM. It is important for personnel working in the AE program to remember that the NAVAIRSYSCOM AE program is firmly tied to RCM. The information gained during an AE analysis for resolving defaulted RCM decisions must be fed back to update the RCM analysis in order to determine the best PM task and interval. The following paragraphs of this chapter will address specific areas where AE results are used to make changes within a PM program.

a. Adjusting Maintenance Intervals. As a result of an AE task, it may be found that the existing maintenance interval is not the most effective interval. The results of the AE task will provide the potential failure to functional failure interval or HT interval for the particular piece of equipment under analysis. By entering the new engineering interval into the RCM analysis a revised PM requirement will be developed.

b. Adjusting Maintenance Tasks. At the completion of an AE analysis, one of the results may be the adjustment of the existing scheduled maintenance task. The task adjustment may require such things as changing the inspection method, adding more requirements, deleting requirements, or changing the PM task altogether (i.e. going from an OC inspection to a HT removal). AE results are used to update the RCM to accomplish these changes.

c. Modifying Age Exploration Sampling/Programs. Another output of an AE task may be the recommendation of modifying the present AE task to obtain the required results. The task modification may be as simple as changing the number of samples which will undergo analysis or as complex as rewriting the inspection task and data recording process. An effective AE program will undergo constant modifications, such as adding new AE candidates, deleting completed or unsuccessful tasks, changing sample sizes, or adjusting task intervals. A good program will require a continuous system of tracking all tasks and recording the information collected.

d. Design Changes. A redesign requirement for an item is considered the least favorable result from an AE task. However, it is perfectly reasonable and valid when the results of AE does not justify a preventive requirement. Redesign must be considered as an alternative to a PM requirement in some cases, and may be required in other cases (i.e. safety or high costs).

4.3.4 RCM Cost Benefits. One of the basic principles of RCM is that PM is accomplished at the least expenditure of resources. Costs and benefits must be documented to allow us to answer the question "Is the program providing a return on investment?" In order to assess the cost avoidances/savings, a baseline must first be established with which RCM developed PM requirements can be compared. For existing equipment, this baseline will be the existing PM and AE program. For new acquisition programs, there will not be a PM program to collect data from. Therefore, the aircraft being replaced should be used to determine the baseline to compare to the current PM program. Next, the cost of performing the RCM analysis must be determined. After the analysis is performed, the new PM requirements along with their associated costs should be recorded. Changes in requirements for all levels of maintenance should be documented. With all of this information documented, the change in cost (or avoidances) due to these changes (intervals which have been extended/shortened and tasks which have been eliminated/added) can be determined and supported.

4.3.4.1 Calculating RCM Cost Avoidances/Savings To determine benefits of RCM, we must perform a comparison of the cost of RCM with our baseline PM costs.

$$\mathbf{C_{BL} = C_{OPR}}$$

C_{BL} = Baseline PM costs

C_{OPR} = Operating Costs - Cost of performing PM and AE tasks (see 4.3.4.3)

$$\mathbf{C_{RCM} = C_{INV} + C_{OPR}}$$

C_{RCM} = RCM costs as determined from application of RCM and the revised tasks

C_{INV} = Investment costs to develop and maintain PM program (see 4.3.4.2)

C_{OPR} = Operating Costs - Cost of performing PM and AE tasks (see 4.3.4.3)

Cost avoidances/savings of RCM are determined by comparison of C_{BL} with C_{RCM}. This can be applied at the significant item level, system level, or at the end item, to determine the overall benefits of the RCM program. Appendix D provides a detailed example of a RCM cost avoidance calculation.

A significant RCM cost avoidances/savings can be realized in the elimination or extension of HT task intervals. This allows for equipment to achieve its inherent reliability, continue in operation longer, and decrease Aviation Depot Level Repair (AVDLR) costs.

These cost calculations can be automated utilizing spreadsheets, or other software programs. This allows for timely accounting of all associated RCM cost avoidances/savings.

4.3.4.2 Investment Costs. Investment costs are those which must be made to develop and maintain the PM and AE processes. The investment costs include analysis and documentation, but do not include actually accomplishing the PM requirements. To determine investment costs of the RCM developed program, record those costs associated with the analysis (man-hours, and cost per man-hour). Training and other data costs (if incurred) can be pro-rated and also included as an investment cost.

4.3.4.3 Operating Costs. Operating costs are those which are required to actually accomplish PM and AE requirements at whatever maintenance level is necessary. Operating costs need to be determined for both the baseline and the RCM developed program. To determine PM and AE operating costs, record those costs associated with each PM or AE requirement (material costs to do inspections, direct maintenance man-hours (DMMH), cost/DMMH, cost to repair functional failures). When calculating the cost of the new PM program, determined through a RCM analysis, it is important to use the same factors used to determine the cost of the baseline (see paragraph 4.3.4.1). Using different factors will not allow a valid comparison between the pre-RCM PM program and the post-RCM PM program.

4.3.5 Other Benefits of RCM. In addition to cost savings, other important benefits result from the application of RCM. Improvements in safety and operational availability can be partially attributed to the PM program improvements caused by RCM. These and any other benefits associated with the application of RCM should be documented as they occur.